FREIGHT WING INC.™
Driving Fuel Efficiency Into Tomorrow

Final Technical Report

Freight Wing Second Generation Trailer Aerodynamics

October 31, 2007

Freight Wing Incorporated
4015 49th Ave SW
Seattle, WA 98116
sean@freightwing.com
206-769-7880

Award Number: DE-FG36-05GO15158

Contact:
Sean Graham (Principal Investigator)
sean@freightwing.com
206-769-7880

Project Team:
Lisa Barnett (DOE HQ Program Manager)
Deborah Weems (DOE Field Project Officer)
Kim Cierpik (Project Engineer/Monitor)

Executive Summary

Freight Wing Incorporated utilized the opportunity presented by a DOE category two Inventions and Innovations grant to commercialize and improve upon aerodynamic technology for semi-tuck trailers capable of decreasing heavy vehicle fuel consumption, related environmental damage, and U.S. consumption of foreign oil. Major project goals included the demonstration of aerodynamic trailer technology in trucking fleet operations, and the development and testing of second generation products.

A great deal of past scientific research has demonstrated that streamlining box shaped semi-trailers can significantly reduce a truck's fuel consumption. However, significant design challenges have prevented past concepts from meeting industry needs. Freight Wing utilized a 2003 category one Inventions and Innovations grant to develop practical solutions to trailer aerodynamics. Fairings developed for the front, rear, and bottom of standard semi-trailers together demonstrated a 7% improvement to fuel economy in scientific tests conducted by the Transportation Research Center (TRC). Operational tests with major trucking fleets proved the functionality of the products, which were subsequently brought to market.

This category two grant enabled Freight Wing to further develop, test and commercialize its products, resulting in greatly increased understanding and acceptance of aerodynamic trailer technology. Commercialization was stimulated by offering trucking fleets 50% cost sharing on trial implementations of Freight Wing products for testing and evaluation purposes. Over 230 fairings were implemented through the program with 35 trucking fleets including industry leaders such as Wal-Mart, Frito Lay and Whole Foods. The feedback from these testing partnerships was quite positive with product performance exceeding fleet expectations in many cases. Fleet feedback also was also valuable from a product development standpoint and assisted the design of several second generation products intended to further improve efficiency, lower costs, and enhance durability. Resulting products demonstrated a 30% efficiency improvement in full scale wind tunnel tests. The fuel savings of our most promising product, the "Belly Fairing" increased from 4% to 6% in scientific track and operational tests.

The project successfully demonstrated the economic feasibility of trailer aerodynamics and positioned the technology to realize significant public benefits. Scientific testing conducted with partners such as the EPA Smartway program and Transport Canada clearly validated the fuel and emission saving potential of the technology. The Smartway program now recommends trailer aerodynamics as a certified fuel saving technology and is offering incentives such as low interest loans. Trailer aerodynamics can save average trucks over 1100 gallons of fuel an 13 tons of emissions every 100,000 miles, a distance many trucks travel annually. These fuel savings produce a product return on investment period of one to two years in average fleet operations. The economic feasibility of the products was validated by participating fleets, several of which have since completed large implementations or demonstrated an interest in volume orders. The commercialization potential of the technology was also demonstrated, resulting in a national distribution and manufacturing partnership with a major industry supplier, Carrier Transicold. Consequently, Freight Wing is well positioned to continue marketing trailer aerodynamics to the trucking industry. The participation of leading fleets in this project served to break down the market skepticism that represents a primary barrier to widespread industry utilization. The benefits of widespread utilization of the technology could be quite significant for both the transportation industry and the public. Trailer aerodynamics could potentially save the U.S. trucking fleet over a billion gallons of fuel and 20 million tons of emissions annually.

Project Description

1. Original Project Goals and Objectives

The original project goals and objectives as outlined in our project management plan are as follows:

Task 1: Commercialization/Testing of Existing Products
Freight Wing will sell testing projects of five or more fairings from our current product line to large trucking fleets at half the current retail price. Fleets will provide valuable product feedback and serve as an example to the industry to break down market barriers.

Task 2: New Product Development
Freight Wing will develop a new line of products using composite materials to lower end user costs, enhance durability, and maximize fuel savings. Prototypes will be fabricated by our manufacturing partners Koneta and KMS and new manufacturing methods will be investigated.

Task 3: Belly Fairing Comparison Testing
A new composite belly fairing prototype will be placed in a fleets normal operation to test functionality, durability, and estimate improved fuel economy. The existing belly fairing design will also be tested in the same operating environment to provide comparison feedback.

Task 4: Product Optimization
Throughout the project, Freight Wing will use the feedback and/or data generated by testing projects to optimize the design of existing and new products. Freight Wing will create additional small scale tests when necessary to analyze new prototypes.

Task 5: New Belly Fairing Fleet Testing
Using the feedback generated in task three to optimize the design, five new belly fairing prototypes will be fabricated and placed in a large fleet's normal operation to gain a wider scope of feedback regarding product performance.

Task 6: New Product Fuel Economy Testing
New products will be tested to determine their fuel saving performance by a respected third party using standardized test procedures.

Task 7: Commercialization/Testing of New Products
Freight Wing will sell testing projects of five or more fairings from our new product line to large trucking fleets at half the retail price. Fleets will continue to provide valuable product feedback and serve as an example to the industry to break down market barriers.

Task 8: Business Development
Throughout the project, Freight Wing will expand upon its existing business foundation. Funding, income and purchases will be accurately accounted for and all business operations will be managed to complete the project objectives.

Task 9: Product Marketing
Throughout the project, Freight Wing will develop and execute its marketing strategy. All potential sales channels will be pursued. Freightwing.com, PR efforts, and tradeshows will increase market awareness. Marketing materials will be generated and distributed.

Task 10: Intellectual Property Development
Patent applications resulting from new product development will be will be drafted and submitted as necessary throughout the project and new inventions will be reported to the DOE.

Task 11: DOE Report Submission
Reports outlining the project's progress, achievements and goals will be submitted to the DOE

2. Variance From Original Goals and Objectives

Freight Wing successfully completed and in some cases exceeded its original goals and objectives for this project. During the project, several opportunities were presented that enabled us to accomplish more product development, testing and fleet implementations than expected.

Our original product development goals focused on replacing existing belly and gap fairing products with new second generation designs. As the project progressed, several fleet customers came to us with requests to develop products for different equipment configurations such as pup trailers, spread axle trailers, and specialty trailers with equipment that interferes with standard fairing installation. Consequently, several new designs were developed to accommodate a variety of fleet applications. Often the new products utilized the basic design of the standard belly fairing product with new customized features added. By the end of the project, nine new products for different applications were developed.

Freight Wing also expected to hire a respected third party to test new product designs to determine their fuel saving capability. Third party test results using industry standardized SAE/TMC procedures are very important to gaining industry credibility for fuel saving products. Based on our prior testing expedience in our phase 1 project, $50,000 had been budgeted towards this task. However, as the project progressed, Freight Wing received several offers to participate in testing projects that were sponsored by respected organizations including the EPA, Transport Canada and the DOE Heavy Vehicle Project. Because these testing opportunities were performed at no cost to Freight Wing (other than prototype and travel expenses), we were able to complete much more testing than originally planned while reducing our task six budget (with prior DOE approval) from $50,000 to $30,000. The savings realized were utilized to increase our task 7 commercialization budget from $150,000 to $170,000. Consequently, we were also able to complete more fleet implementations than originally expected. Our expectations for fleet implementations were also surpassed by several customers that retuned to purchase more units without cost sharing after initial trials. For example, Robert Transport completed our largest implementation of 155 second generation belly fairing units after an initial trial of 11 test units.

3. Discussion of Work Performed.

The work Freight Wing carried out to complete the project and associated results are outlined by project objective in the following discussion.

Task 1: Commercialization/Testing of Existing Products

The commercialization and testing of previously developed Freight Wing products (illustrated in figure 1 in the supplemental information section) was quite successful with 96 fairings sold and implemented with 16 trucking fleets. Work began by marketing the cost share trial program

to trucking fleets, which offered a 50% discount off retail prices on trial implementations of five or more fairings with free installation services. The program quickly generated sales with existing fleet contacts such as Con-Way, Bison Transportation, and Transport America. For each implementation, Freight Wing sent an installation team to the fleet's location to mount the fairings, train technicians on the procedure and develop relationships with fleet contacts. Through the installation process, Freight Wing personnel gained valuable experience working with different trailer configurations and a great deal of feedback from customers regarding product design, concerns and operational needs. As units were installed, the fabrication of new units continued with our manufacturing partner ASAP Metal in 30 unit production runs.

Continued marketing efforts produced more orders with other respected fleets such as Whole Foods Grocery Stores and Wal-Mart. Wal-Mart initiated a detailed testing program including SAE standardized track tests that demonstrated 6.1% fuel savings with the belly and gap fairing products (fig. 2). Functionality tests such as rail road crossing and loading dock clearance trials were also successfully completed (fig. 3). Whole Foods completed our largest task one implementation of 20 units, which represented the entire trailer fleet at their midwest distribution center. To promote the project, belly fairings were used as a platform for graphics stating "This Aerodynamic Trailer Reduces Fuel Consumption and Emissions" (fig 4). According to Whole Foods, the implementation produced a .25 mpg overall improvement in the fleet's fuel efficiency. A leading industry publication, Transport Topics, interviewed a Whole Foods representative for a February 2006 article who claimed, "This product really helped. We heard from our drivers that they were experiencing increases in fuel efficiency of 4% to 5%". Positive feedback from early trial participants help us generate additional sales with Dick Salem trucking, Hiner Transport, Bentex and Brockway Smith. As fleet testing continued, fuel economy results exceeded expectations. Two fleets, Hiner Transportation and Hirschbach Motor Lines, conducted detailed on road fuel economy studies with on board fuel economy tracking systems. Hiner Transportation placed 13 Belly Fairings on a high mileage dedicated route, and averaged a .3 mpg or 4.8% improvement. Hirschbach Motor Lines conducted a similar study on 5 trailers and demonstrated a 6% improvement. Fleet feedback on durability, driver impressions and functionality were also positive. Although some problems with accidental damage due to driver error were reported, the fairings withstood demanding operating conditions well. An early concern of snow and ice build up did not represent an issue during winter months. The lowered trailer clearance of the belly fairing did not cause damage in steep loading docks and rail road crossings, which had also been a primary concern. Task one testing also provided a great deal of technical feedback that provided a solid foundation for second generation product design.

Task 2: New Product Development

Several second generation fairing designs were developed through the project to improve performance, enhance durability and address the needs of different fleets. New materials such as composite panels and durable "polyrubber" were employed as well as new manufacturing methods. Our efforts in this task were largely driven by feedback and requests from our fleet partners. Resulting new products included, The "Low Rider" belly fairing, the NXT leading edge fairing, a spread axle trailer fairing, the wing tip belly fairing, pup trailer fairings and stainless steel fairings.

Early product development efforts focused on new belly fairing designs, as this area has demonstrated the largest fuel saving potential. In an effort to reduce costs and improve durability, a composite rubber material called "nyracord" was employed on our fist two belly fairing prototypes (fig. 5). An aluminum frame and mounting components were fabricated to support the nyracord in an aerodynamic geometry similar to the standard belly fairing product.

Two units of this design with different nyracord thicknesses were placed in operation with J line transportation (see task 3). Although the units performed well in operational tests, increased weight and installation times were disadvantages that led us to consider more options. Full scale wind tunnel tests conducted in 2003 with the Canadian NRC (see task 6) also reveled that extending the fairings closer to the ground with a flexible rubber material can improve performance by 30% (fig 15). Our next design incorporated this low clearance feature, using the same aluminum frame as the previous prototypes. A fiberglass composite material called Bulitex was employed instead of the nyracord to reduce weight and improve rigidity. Three of these units (fig. 6) were place in operation with a major Canadian fleet called Robert Transport, which participated in the wind tunnel testing project. Robert also placed four modified versions of the standard belly fairing in operation that featured an aerodynamically curved front section made of the bulitex material (fig. 7), These prototypes also performed well in operation, however the bulitex material was not as efficient to fabricate as aluminum because it cannot be automatically cut with a laser cutter, resulting in increased production costs. Consequently, we developed another version incorporating the best features of both designs using aluminum panels and a flexible lower flap, which was tested with Robert in 2006. This prototype resulted on our final production second generation belly fairing, which we are marketing as the “Low Rider” belly fairing (fig. 8). The Low Rider belly fairing has been our most successful new product both in terms of sales and fuel savings. The product demonstrated a 6% fuel saving in a SAE standardized test conducted Robert and Transport Canada at the PMG technologies test track (see task 6). Robert has since purchased and implemented 155 low rider units in fleet operations, serving to validate the success of our second generation product development.

New product development also resulted in several modifications to the standard belly fairing product to improve performance and accommodate different fleet needs and equipment configurations. Initial designs replaced the triangular front panel of the standard product with a larger panel that angled inward to improve aerodynamic coverage (fig. 9). A design for small 28 foot “pup” trailers was created by omitting one side panel. (fig. 10). The standard design was also outfitted with an additional wind deflector on the rear lower corner of the fairing to help guide additional airflow around the wheels (fig. 11). This product, now called “wing tips” demonstrated a .25% improvement in fuel economy in NRC wind tunnel tests and also serves to improve product appearance. Three fairings were fabricated out of stainless steel for customers that wanted improved aesthetics despite increased cost (fig. 11). A design was also created for spread axle trailers that featured a panel between the trailers wheels (fig. 12).

Second generation gap fairing development was also completed during the project. The resulting “NXT Leading Edge Fairing” focuses on the smoothing airflow over the front/top edge of the trailer (fig. 13). Prior research has indicated that this top edge is exposed to the largest amount of drag causing airflow. By focusing on that area only, the NXT is a very simple product that is very inexpensive to manufacture. It is made from durable polyrubber material and is therefore much more resistant to damage than the standard gap fairing. The NXT was tested in the NRC full scale wind tunnel tests and demonstrated a 3.7% reduction in drag when used with a mid roof tractor. NXT prototypes were also placed in operation with our partner fleet, J-line Transportation. The prototypes performed well for J-line and have since been demonstrated with other fleet partners such as KMS trucking.

Task 3: Belly Fairing Comparison Testing

We gained a great deal of belly fairing comparison feedback through the testing competed by J-line Transportation and Robert Transport. Our fist two belly fairing prototypes were placed in operation with J-line transportation in 2005 (fig. 5). One fairing utilized thicker .25

in composite rubber “nyracord” sheeting and the other a thinner .125 sheet. Both units performed well in operations and J-line reported a ½ mpg fuel economy improvement, which is approximately a 6% savings. The tests enabled us to determine that the thinner material is adequate and preferable due to decreased weight and cost. When compared to standard units, the new prototypes produced more fuel savings and better durability, but weighed more and were more difficult to install. This led us to develop other prototypes, which were tested with Robert Transport for comparison feedback. Robert tested three composite fairings (fig. 6), five aluminum fairings with a curved composite front section (fig.7), and one standard fairing. The different belly fairing designs implemented by Robert all performed well and Robert expressed an interest in combining several design features of the different prototypes. This input served as a basis for the Low Rider design (fig. 8), which incorporates the best features of all three designs including aluminum side panels, a flexible lower flap, and a curved front section.

Task 4: Product Optimization

Testing projects produced valuable feedback for product optimization that was incorporated in the old and new products. Changes made to the standard belly fairing included increasing the aluminum sheet thickness from .05 inches to .065 inches, using stronger ¼ inch diameter rivet fasteners, adding rubber bonded washers to fastening points to decrease vibration wear, the addition of braces to the lower flap to prevent sagging in snow conditions, and the use of vapor barrier tape to prevent galvanic corrosion. The standard gap fairing also saw many improvements including replacing welds with fasteners to reduce product costs and improve durability. Freight Wing also incorporated several of these improvements to optimize next generation product designs. Fleet feedback on early second generation prototypes allowed us to optimize the production Low Rider belly fairing by removing lower flap braces that were found to be unnecessary. The NXT leading edge fairing design was also optimized based on input from road tests by increasing the degree of bend in the sheet material to increase rigidity.

Task 5: New Belly Fairing Fleet Testing

Task five was expanded to take advantage of several testing opportunities presented by respected fleets to test the new belly fairing configurations developed in task 2. Instead of testing 5 units of one new design with one fleet as originally planned, we tested five new designs with five different fleets. One of the largest truckload carriers in the US, Swift transportation, conducted testing on one of the initial second generation belly fairings that featured an angled front section (fig. 9). Our first stainless steel belly fairing was tested with Kool trucking. May trucking, a major truckload fleet based in Oregon, tested a modified belly fairing with a “wing tip” on the lower flap to enhance aerodynamic performance. A belly fairing for spread axle trailers with a small segment of fairing placed between the wheels was tested with Kufall transport. Our first Low Rider belly fairing was also tested by Robert Transport. Feedback from the testing fleets on the new products was quite positive and several suggestions for improvements were utilized to help optimize the designs. Partners did not experience operational problems and the fuel savings were in line with expectations. The experience of installing the new designs also allowed us to realize and resolve potential problems for production units such as misplaced rivet holes.

Task 6: New Product Fuel Economy Testing

Task six was significantly expanded as Freight Wing was given the opportunity to participate in several fuel economy testing projects that were sponsored by other organizations including the EPA, Transport Canada and the DOE heavy vehicle project. The EPA Smartway program

featured Freight Wing products in two separate fuel economy testing projects. The first was conducted using a "modified SAE test procedure" at the Aberdeen proving grounds. Results were published in a 2005 SAE paper #05CV-45. In this test, the Freight Wing belly fairing was used in combination with our gap fairing and a "boat tail" rear fairing developed by another company (Aerovolution), which claims a 3.5% fuel savings. Data indicated that the aerodynamic trailer produced a 12% fuel economy gain at 65 mph. The EPA also hired the Southwest Research Institute to perform a second round of SAE standardized testing in the spring of 2006. The results of this project were published in SAE paper 2006-01-3474. The Freight Wing belly fairing and gap fairing demonstrated a 10.2% fuel savings in combination with single wide tires in a 65 mph drive cycle.

In March 2006, Freight Wing had the opportunity to participate in a full scale wind tunnel testing project sponsored by the National Research Counsel (NRC) of Canada that was open to several developers of aerodynamic technology. The NRC has one of the world's largest and most sophisticated wind tunnel facilities based in Ottawa (fig. 15). Results, published in SAE paper 06CV-222, indicated a 3.7% reduction in wind averaged drag coefficient at 55 mph with the standard belly fairing. According to the NRC's method of estimating fuel savings from wind tunnel data, this result should produce 4.2% fuel savings at 65 mph. Freight Wing also tested a prototype "Low Rider" Belly Fairing that extended the aerodynamic coverage closer to the ground with flexible rubber material. The Low Rider produced a 30% improvement in drag reduction over the standard version.

As a follow up to the wind tunnel test, SAE standardized fuel economy tests were conducted on the Low Rider belly fairing design in partnership with Robert Transport and Transport Canada at PMG technologies (Canada's leading test facility: http://www.pmgtest.com). The tests demonstrated a 5.8% reduction in fuel consumption with the Low Rider design alone.

We also received test results from a testing project initiated by Volvo and Great Dane trailers, in cooperation with the DOE Heavy Vehicle Project. SAE testing at the Transportation Research Center was completed in 2006. Results indicated an 8% fuel savings with the Belly Fairing combined with a rear fairing from another company and an unknown "enclosure" device.

Freight Wing was fortunate to have the opportunity to test its products with these respected institutions, and our products now represent the most thoroughly evaluated aerodynamic trailer attachments available to the tucking industry.

Task 7: Commercialization/Testing of New Products

The success our product development and testing allowed us to begin the commercialization/testing of new products ahead of our anticipated schedule. As in task 1, Freight Wing began by marketing the cost share trial program to trucking fleets, which offered a 50% discount off retail prices on trial implementations of five or more second generation fairings with free installation services. The first second generation fairings sold featured a door in the fairing to access control boxes for lift gate trailers. Advance Auto Parts implemented five of the door fairings. Continued marketing efforts produced more orders with other respected fleets such as Sherman Williams, Falcon transport, Twin City Transportation, Frito Lay, New Century, Logistics Management, Messilla Valley, and Miller Expedited Freight. In all, five different second generation fairings were used on these different fleets. Several fleets implemented fairings with "wing tip" air deflectors (fig 11). Sherman Williams and Frito Lay implemented customized fairings to fit shorter 28' pup trailers as well as full length fairings that were modified to accommodate side door ladders (fig 10). A fleet called Logistics Management implemented five

fairings for spread axle trailers (fig. 12). In total, 135 second generation fairings were implemented during the completion of this task with 19 fleets. Feedback from partner fleets has been quite positive. Fuel savings have been in line with expectations and only minor accidental damage was reported due to driver error. We were very pleased to see return customers, which serves to validate the acceptance of the next generation products. Several fleets have also inquired about larger implementations that we hope to move forward with in 2008.

Task 8: Business Development

Freight Wing used this project to improve its business foundation in task 8 to support continued commercialization efforts. Business development focused on establishing sales channels, financing, accounting, and operations. Initial efforts concentrated on launching the fleet trial program (task one) by developing our direct fleet sales channel. Eventually the program also helped us establish sales channels through trailer dealers such Trudell trailers and independent sales representatives in Arkansas, Illinois, and the Carolinas. As sales volume increased, managing installations, production and fabricator relationships also became a business development priority. Freight Wing worked with several manufacturers and suppliers to reduce product costs and improve sales margins. Requests for volume quotes from large fleet partners such as Wal-Mart led us to consider a wide range of supply options and develop volume pricing tiers. Throughout the project, we were able to reduce the production cost of standard units over 20%.

As industry interest in our products increased, Freight Wing pursued distribution with major trailer manufacturers (OEM's). Meetings and demonstration installs were conducted with Wabash National, Great Dane, Utility and Strict trailer manufactures. Contacts demonstrated a high level of interest, although many related that a clear customer demand would need to be established before proceeding with sales programs. Since then, several OEM's have received interest from customers and Freight Wing has worked with two of the largest manufacturers, Utility and Great Dane, to provide quotes for factory installations. In 2006, Freight Wing also developed a manufacturing and national distribution partnership with Carrier Transicold. Carrier is a leading brand of truck refrigeration units and auxiliary power units (APU's), which are also designed to save fuel and therefore fit our product line well. This partnership represents a great opportunity for us to market, distribute and install our products, with a well respected brand in the trucking industry. Carrier has over 200 dealerships across North America that are currently marketing Freight Wing products and also provide installation services. Carrier is also using its significant manufacturing capabilities to fabricate the products, enabling us to reduce costs and generate an acceptable margin on sales through their channels. This arrangement will further benefit Freight Wing by enabling us to purchase units from them at a reduced cost for direct sales.

With our expanding business also came the need to acquire more capital to maintain growth. A business line of credit was established along with a loan from our primary investor to give us the capital we needed to effectively manage cash flow. We also continued working on a new business plan in anticipation of proceeding with fundraising efforts in 2007. We plan on announcing a second round of private equity financing next quarter to raise 500K to support our continued development.

Task 9: Product Marketing

Throughout this project, Freight Wing developed and executed a detailed marketing strategy.

Our marketing efforts initially focused on developing a press release to promote the trial program in industry publications. The press release was quite successful with over 15 articles generated in industry publications. Freight Wing received several leads from the press that were eventually converted into sales. The development of our website, www.freightwing.com, was also an early priority that has remained a primary means of establishing customer relationships. Marketing materials including sales folders, brochures, flyers, postcards, informative computer cd's, and technology summaries were also generated and distributed to contacts.

Freight Wing exhibited at major industry trade shows on a regular basis throughout the project as a part of our marketing plan. The MATS, TMC and GATS trade shows were a primary means of developing relationships with major customer fleets. These trade shows led us to other events including The Fuel Economy Clean Technologies Forum and The Efficient Diesel Workshop sponsored by the Columbia-Willamette Clean Cities Coalition. These events gave Freight Wing the opportunity to present our products to important industry representatives and helped us establish relationships with the EPA Smartway program, Carrier Transicold, May Trucking, and Cascades Sierra Solutions. As a result, we were able to display our product in the Cascade Sierra Solutions Colburg, Oregon truck stop showroom.

At the MATS show in August 2006, we had the opportunity to become a part of the American Trucking Association (ATA) by outfitting their "Share the Road" trailer with Freight Wing aerodynamics (fig. 14). This trailer is part of a PR tour promoting highway safety that will be featured in many events and will obtain great exposure for Freight Wing over the next several years.

Marketing efforts at the end of this project focused on developing our partnership with Carrier Transicold and helping them market the product through their dealer sales channels. New marketing materials including a 4 page color brochure, web site, ROI calculator and internal sales documents were developed with the Carrier team.

Task 10: Intellectual Property Development

During this project, Freight Wing was awarded patent #7,093,889 for the belly fairing. This patent represents our most important intellectual property, as the belly fairing has clearly demonstrated the most commercialization potential. Freight Wing was previously awarded two other patents for our rear fairing (#6,854,788) and gap fairing (#7,008,005) products that were developed during our category one grant. Although several new products were developed during this project, all of them were modifications of the basic belly and gap fairings inventions. Considerable research for potential patent applications on the new product designs was completed during this project. The most novel new product developed during this project was determined to be the Low Rider belly fairing due to its flexible lower flaps. After consulting with our patent advisor, we decided not to pursue a new patent application for the Low Rider belly fairing design. Our existing belly fairing patent covers many aspects of the new design, which provides some protection against imitation, and also makes the novelty of a new application questionable. Further modifications to the design could greatly reduce the product's cost and improve its chances of widespread adoption. Further improvements may also add to the novelty of the design to increase our chances of a patent application's acceptance. Consequently, we plan on further developing the design in the future and reconsidering a new application when we are confident the technology is sufficiently novel for patent acceptance.

Task 11: DOE Report Submission

All quarterly reports and this final report were prepared and submitted on time.

4. Conclusions and Recommendations for Future Work

Freight Wing made significant progress toward its goal of saving oil, money and emissions through the assistance of this DOE Inventions and Innovations grant opportunity. Second generation product development resulted in several new designs for aerodynamic trailer fairings. Products for different trailer configurations such as pup and spread axle trailers greatly expanded our ability to serve fleets with different equipment and operating conditions. Product performance was also greatly improved, resulting in a new belly fairing capable of producing 6% fuel savings. Extensive scientific testing was completed with respected partners such as the EPA Smartway program, Transport Canada and the DOE Heavy Vehicle Project, which clearly validated the fuel and emission saving capabilities of the products. The commercial potential of trailer aerodynamics was also clearly demonstrated, with 231 units sold to 35 fleet partners though the project's cost share trail program. The feedback from fleet partners was quite positive, and several customers have proceeded with larger implementations or inquired about volume orders. Fleet demonstrations served to break down the market skepticism that represents a primary barrier to the industry's acceptance of trailer aerodynamics. Commercialization success enabled the creation of new distribution channels through trailer manufacturers and Carrier Transicold's national dealer network. Manufacturing also became much more efficient and economies of scale served to reduce production costs. Freight Wing aerodynamic trailer technology is now well positioned to help the trucking industry reduce fuel consumption and emissions while providing financial savings. However, the technology is still underutilized and its adoption in the trucking industry could be greatly accelerated with further government assistance.

Recommendations for future work include improving manufacturing efficiencies to reduce product costs and offering government incentives to motivate the widespread implementation of trailer aerodynamics. Although existing aerodynamic trailer technology can produce significant long term financial returns, up front cost is a primary barrier to adoption. Due to the competitive nature of the trucking industry and the large capitol requirements of standard equipment, fleets typically have limited resources available to invest in efficiently improvements. Improving the manufacturing efficiency of trailer aerodynamics could potentially reduce the end user cost significantly. Government incentives such as tax rebates, low interest loans, and cost share funding would also provide much needed financial assistance to motivate the implementation of the technology. The widespread implementation of trailer aerodynamics would produce large returns on government investments through substantial oil and environmental savings. Energy savings estimates outlined in appendix D indicate that the U.S. truck fleet could potentially save up to 400 trillion BTU's annually by 2010 through aerodynamic trailer technology.

Appendices

Appendix A
Final Task Schedule

Final Task Schedule

Task Number	Task Description	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
1	Commercialization/Testing of Existing Products	8/1/2006		8/1/2006	100%	Complete
2	New Product Development	8/1/2006		8/1/2006	100%	Complete
3	Belly Fairing Comparison Testing	8/1/2006		8/1/2006	100%	Complete
4	Product Optimization	2/1/2007		9/30/2006	100%	Complete
5	New Belly Fairing Fleet Testing	8/1/2006		8/1/2006	100%	Complete
6	New Product Fuel Economy Testing	11/1/2006		9/30/2006	100%	Complete
7	Commercialization/Testing of New Products	7/31/2007		5/30/2007	100%	Complete
8	Business Development	7/31/2007		6/30/2007	100%	Complete
9	Product Marketing	7/31/2007		6/30/2007	100%	Complete
10	Intellectual Property Development	7/31/2007		6/30/2007	100%	Complete
11	DOE Report Submission	7/31/2007		7/31/2007	100%	Complete

Appendix B
Final Spending Schedule

Project Period: 8/01/05 to 7/31/07

Spending Schedule

Task		Approved Budget	Final Project Expenditures
Task 1	Commercialization/Testing of Existing Products	150,000	147,987
Task 2	New Product Development	18,000	17,997
Task 3	Belly Fairing Comparison Testing	3,500	3,430
Task 4	Product Optimization	12,000	11,928
Task 5	New Belly Fairing Fleet Testing	6,500	6,439
Task 6	New Product Fuel Economy Testing	30,000	29,621
Task 7	Commercialization/Testing of New Products	170,000	174,764
Task 8	Business Development	75,000	105,990
Task 9	Product Marketing	75,000	108,383
Task 10	Intellectual Property Development	9,000	8,932
Task 11	DOE Report Submission	1,000	1,000
Total		550,000	616,471
DOE Share		250,000	250,000
Cost Share		300,000	366,471

Appendix C
Final Cost Share Contributions

Final Cost Share Contributions

Funding Source	Approved Cost Share		Final Contributions	
	Cash	In-Kind	Cash	In-Kind
Freight Wing Inc.	300,000		366,471	
Total	300,000		366,471	
Cumulative Cost Share Contributions			366,471	

Appendix D
Energy Savings Metrics

Discussion of Energy Savings:

The energy savings made possible by Freight Wing products were experimentally derived during the course of this project as well as during our category one grant. In our first project, SAE/TMC J1321 type II fuel economy tests conducted by the Transportation Research Center (TRC) demonstrated a 7% reduction in the fuel consumption of a fully loaded semi truck with the belly, gap and rear fairing in combination. Individually, the belly fairing produced a 4% savings, the gap fairing a 2% savings and the rear fairing a 1% savings. The TRC report is available by request and for download at freightwing.com. During this project, our second generation "Low Rider" belly fairing produced a 6% fuel savings in SAE standardized fuel economy tests completed by PMG technologies. Therefore when the second generation belly fairing is used in combination with the gap and rear fairings, Freight Wing products can produce a total fuel savings of 9%. This level of fuel savings was further validated by two testing projects completed by the EPA Smartway Program, that demonstrated12% and 10.2% fuel savings using aerodynamic trailers and single wide tires (see task 7). The 9% combined product fuel savings realized during this project is close to our original project expectations of 10%.

Calculations

One Unit of Current Technology: One tractor-trailer combination with a loaded van (box shaped) trailer.

According to the U.S. Department of Transportation, Federal Highway Administration, *Highway statistics 2001* report, there were 2,154,000 combination trucks registered in the U.S., which traveled a total of 135,400 Million miles, at an average fuel economy of 5.3 miles per gallon. Note that there are more trailers registered than trucks (4,864,350) because fleets typically employ more trailers to make loading/unloading operations more efficient.

The average truck therefore traveled:
135,400,000,000 miles / 2,154,000 trucks = 62,860 miles / truck

And used:
(62,860 miles / truck) / (5.3 miles/gallon) = 11,860 gallons of fuel per year

In energy terms:

11,860 gallons of fuel/year X 126,000 Btu/gallon = 1,494 Million Btu/year

One Unit of Proposed Technology: One tractor-trailer combination with a loaded van (box shaped) trailer, employing Freight Wing Products (the gap, Low Rider belly and rear fairings).

Using figures from the previous calculations, the 9% fuel savings demonstrated by Freight Wing products would lower and average trucks annual fuel consumption by:

11,860 gallons/year X 9% = 1,067 gallons/year

Resulting in a total consumption of:

11,860 gallons/year – 1,067 gallons/year = 10,793 gallons/year

In energy terms:

10,793 gallons of fuel/year X 126,000 Btu/gallon = 1,359 Million Btu/year

Estimated Number of Units in 2010

According to the *Highway statistics 2001* report, there were 1,675,000 combination trucks registered in the U.S. in 1992 and 2,254,000 in 2001. Therefore, the U.S. combination truck population grew by 29% in 9 years. Assuming this trend continues, there will be:

2,254,000 trucks + 2,254,000 trucks X 29% = 2,908,000 combination trucks (units) in 2010

Total Energy Savings

Using figures from the previous calculations, each combination truck (unit) will save:

1,494 Million Btu/year - 1,359 Million Btu/year = 135 Million Btu/year/unit

Multiplied by the estimated truck population in 2010:

135 Million Btu/year/unit * 2,980,000 units = 402,300,000 Million Btu/year

Existing Freight Wing products could potentially save the U.S. over 400 Trillion Btu's per year by 2010.

Energy Savings Metrics

	A	B	C=A-B	D	E=CxD
Type of Energy Used	**Current Technology (Btu / yr / unit)**	**Proposed Technology (Btu / yr / unit)**	**Energy Savings (Btu / yr / unit)**	**Estimated Number of Units in U.S. by 2010 (units)**	**Energy Savings by 2010 (Btu / yr)**
Oil / Gasoline	**1,494 Million**	**1,359 Million**	**135 Million**	**2.98 Million**	**402.3 Trillion**

Supplemental Information

Figure 1: Prior Freight Wing Products

Figure 2: Wal-Mart Belly and Gap fairings

Figure 3: Wal-Mart Functionality Testing

Figure 4: Belly Fairing Wing Graphics on a Whole Foods Trailer

Figure 5: Freight Wing Nyracord Belly Fairing Prototype

Figure 6: Freight Wing Composite Low Clearance Belly Fairing Prototype

Figure 7: Freight Wing Curved Front Belly Fairing Prototype

Figure 8: Freight Wing Low Rider Belly Fairing

Figure 9: Freight Wing Angled Front Belly Fairing Prototype

Figure 10: Freight Wing Pup Trailer Configuration

Figure 11: Freight Wing Stainless Steel and Wing Tip Belly Fairing

Figure 12: Freight Wing Spread Axle Trailer Belly Fairing

Figure 13: Freight Wing NXT Gap Fairing

Figure 14: American Trucking Association demo/PR Trailer

Figure 15: Full Scale Wind Tunnel Testing with the Canadian NRC